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Title of the Invention



~~Contention Control with State Machine~~

Background of the Invention

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*1. Field of the Invention*

This invention relates to point-to-multipoint communication. In particular, the invention relates to control of contention for data slots by customer premises equipment in a wireless point-to-multipoint communication system.

## 2. Description of the Related Art

In a point-to-multipoint network, plural customer provided equipment (CPEs) communicate bidirectionally with a base station controller (BSC) in a cell. Several CPEs can share a single channel for communicating with the BSC. The CPEs and the BSC use time division duplexing (TDD) to facilitate the bidirectional aspect of the communication. The CPEs and the BSC use time division multiple access (TDMA) to facilitate sharing of a channel among plural CPEs.

In TDMA, the BSC grants data slots to the CPEs. Because multiple CPEs share a limited number of data slots, the CPEs and the BSC must negotiate data slot assignments through a process called contention.

In contention, CPEs that have upstream data to send to the BSC first send a short request (REQ) message to the BSC. The BSC responds with a grant of a data slot for use by the CPE.

Problems can arise in contention. First, two CPEs might simultaneously try to use a single request slot to request data slots. This situation is called collision. When collisions occur, neither CPE's request message successfully reaches the BSC. Second, if many request slots are defined so as to reduce a number of collisions and so as to facilitate requests by a large number of CPEs, too much of available bandwidth can be used up by contention traffic. As a result, data throughput can be unacceptably decreased.

1 One technique used in the prior art to reduce contention traffic is called  
2 piggybacking. In piggybacking, a CPE first requests a data slot. When the data slot is granted by  
3 the BSC, the CPE sends data packets upstream. The CPE attaches a size of its current data  
4 backlog to a header for one of the data packets. As a result, whenever the backlog is non-zero,  
5 the BSC knows to grant a data slot to the CPE without the CPE having to send a REQ message.  
6 Thus, contention traffic is reduced.

7  
8 Unfortunately, piggybacking is only effective if upstream traffic from the CPE is  
9 of the bursty type, so that the CPE needs to make only one contention request per burst.  
10 However, some important traffic sources are non-bursty. Examples of non-bursty traffic include  
11 traffic generated by online games and voice sources. Even ordinary Internet traffic running over  
12 TCP becomes non-bursty when a communication link is in heavy traffic. In the presence of  
13 non-bursty traffic, the piggyback scheme breaks down, and an excessive number of contention  
14 requests are sent upstream.

#### 15 16 Summary of the Invention

17  
18 In view of the foregoing, further reducing contention traffic is desirable, especially  
19 for non-bursty traffic. The invention addresses this need by using a new state machine to control  
20 a contention state for a communication link between a base station controller and customer  
21 premises equipment in point-to-multipoint communication. According to the invention, the state  
22 machine includes a grant pending absent state in which the customer premises equipment is  
23 polled with a unicast request slot. During the grant pending absent state, the customer premises  
24 equipment sends no upstream data to the base station controller but can use the unicast request  
25 slot to request a data slot for sending upstream data to the base station controller.

1  
2 By virtue of the grant pending absent state, the customer premises equipment can  
3 request a data slot without entering into contention and generating excess contention traffic.  
4 After a suitable delay without more data being received to send upstream, the state machine can  
5 exit the grant pending absent state. This delay preferably is long enough for receipt of new non-  
6 bursty data for a communication, for example 50 ms.

7  
8 The state machine preferably also includes an idle state in which the customer  
9 premises equipment awaits arrival of data packets to send as upstream data to the base station  
10 controller, a deferring state in which the customer premises equipment requests grant of a data  
11 slot for sending upstream traffic to the base station controller and if necessary defers contending  
12 for the data slot so as to avoid collisions with other customer premises equipment, and a grant  
13 pending state in which the customer premises equipment awaits and receives grant of the data  
14 slot for sending upstream data to the base station controller and sends upstream data to the base  
15 station controller after grant of the data slot.

16  
17 In a preferred embodiment of the invention, the customer premises equipment  
18 uses piggybacking to request grant of a next data slot while sending upstream data to the base  
19 station controller. Use of piggybacking along with the grant pending absent state has been found  
20 to decrease drastically contention traffic.

21  
22 Preferably, the state machine enters the deferring state upon arrival of data packets  
23 to send as upstream data to the base station controller. In the preferred embodiment, the state  
24 machine enters the grant pending state after the deferring state, returns to the deferring state if a  
25 collision occurs, and remains in the grant pending state when sending upstream data to the base

1 station controller with piggybacking. The state machine preferably enters the grant pending  
2 absent state after the customer premises equipment has sent upstream data to the base station  
3 controller in the grant pending state.  
4

5 The state machine according to the invention preferably also includes an  
6 unsolicited grant pending state in which the customer premises equipment receives grant of the  
7 data slot for sending upstream data to the base station controller and sends upstream data to the  
8 base station controller after grant of the data slot, without having requested the data slot. The  
9 state machine preferably further includes an unsolicited grant pending absent state in which the  
10 customer premises equipment is polled with the unicast request slot. During the unsolicited grant  
11 pending absent state, the customer premises equipment sends no upstream data to the base station  
12 controller but can use the unicast request slot to request the data slot for sending upstream data to  
13 the base station controller. Preferably, the state machine enters the unsolicited grant pending  
14 absent state after the customer premises equipment has sent upstream data to the base station  
15 controller in the unsolicited grant pending state.  
16

17 The invention can be embodied in a method for controlling communication using  
18 the state machine described above, as well as in software and/or hardware such as a base station  
19 controller and/or customer premises equipment that implements the method, and in various other  
20 embodiments.  
21

22 This brief summary has been provided so that the nature of the invention may be  
23 understood quickly. A more complete understanding of the invention may be obtained by  
24 reference to the following description of the preferred embodiments thereof in connection with  
25 the attached drawings.

1  
2 Brief Description of the Drawings

3  
4 Figure 1 is a block diagram of a wireless communication system according to the  
5 invention in which a base station controller communicates with one or more customer premises  
6 equipment according to the invention.

7 Figure 2 is a flow chart of a state machine according to the invention.

8  
9 Description of the Preferred Embodiment

10  
11 *Related Applications*

12  
13 Inventions described herein can be used in conjunction with inventions described  
14 in the following documents.

15  
16 U.S. Patent Application Serial No. 09/475,642, Express Mail Mailing No.  
17 EL524780018US, filed December 30, 1999 in the names of Reza Majidi-Ahy, Subir  
18 Varma, Khuong Ngo, Jean Fuentes and Paul Trong, attorney docket number 164.1002.01,  
19 titled "Adaptive Link Layer for Point to Multipoint Communication System."

20  
21 U.S. Patent Application Serial No. 09/475,716, Express Mail Mailing No.  
22 EL524780021US, filed December 30, 1999 in the names of Reza Majidi-Ahy, Joseph  
23 Hakim, and Subir Varma, attorney docket number 164.1003.01, titled "Integrated Self-  
24 Optimizing Multi-Parameter and Multi-Variable Point to Multipoint Communication  
25 System."

1  
2 U.S. Patent Application Serial No. 09/540,674, Express Mail Mailing No.  
3 EL524781512US, filed March 31, 2000, in the name of Reza Majidi-Ahy, attorney docket  
4 number 164.1001.01, titled "Robust Topology Wireless Communication Using  
5 Broadband Access Points."

6  
7 U.S. Patent Application Serial No. 09/604,784, Express Mail Mailing No.  
8 EL524781225US, filed June 26, 2000 in the name of Reza Majidi-Ahy, attorney docket  
9 number 164.1010.01, titled "High-Capacity Scalable Integrated Wireless Backhaul for  
10 Broadband Access Networks."

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and

U.S. Patent Application Serial No. 09/475,716, Express Mail Mailing No.  
EL524780021US, filed December 30, 1999 in the names of Reza Majidi-Ahy, Joseph  
Hakim, and Subir Varma, attorney docket number 164.1003.01, titled "Integrated, Self-  
Optimizing, Multi-Parameter/Multi-Variable Point-to-Multipoint Communication System  
[II]."

Each of these documents is hereby incorporated by reference as if fully set forth  
herein. This application claims priority of each of these documents. These documents are  
collectively referred to as the "Incorporated Disclosures."

### *Lexicography*

The following terms refer or relate to aspects of the invention as described below.  
The descriptions of general meanings of these terms are intended to be illustrative, not limiting.

1 **base station controller (BSC)** — in general, a device for performing coordination and  
2 control for a wireless communication cell. There is no particular requirement that the base  
3 station controller must be a single device; in alternative embodiments, the base station  
4 controller can include a portion of a single device, a combination of multiple devices, or  
5 some hybrid thereof.

6  
7 **communication link** — in general, an element for sending information from a sender to a  
8 recipient. Although in a preferred embodiment the communication links referred to are  
9 generally wireless line of sight point to point communication links, there is no particular  
10 requirement that they are so restricted.

11  
12 **customer premises equipment (CPE)** — in general, a device for performing  
13 communication processes and tasks at a customer location, and operating in conjunction  
14 with the base station controller within a wireless communication cell. There is no  
15 particular requirement that the customer premises equipment must be a single device; in  
16 alternative embodiments, the customer premises equipment can include a portion of a  
17 single device, a combination of multiple devices, or some hybrid thereof.

18  
19 As noted above, these descriptions of general meanings of these terms are not  
20 intended to be limiting, only illustrative. Other and further applications of the invention,  
21 including extensions of these terms and concepts, would be clear to those of ordinary skill in the  
22 art after perusing this application. These other and further applications are part of the scope and  
23 spirit of the invention, and would be clear to those of ordinary skill in the art, without further  
24 invention or undue experimentation.

25  
26 *System Context*

1  
2 The context of the invention is similar to that of the Incorporated Disclosures.

3  
4 A system using point-to-multipoint communication in a wireless communication  
5 system operates as part of a system in which devices coupled to a network (such as a computer  
6 network) send messages, route and switch messages, and receive messages. In a preferred  
7 embodiment, devices coupled to (and integrated with) the network send, route, and receive these  
8 messages as sequences of packets, each of which has a header including delivery information and  
9 a payload including data. In a preferred embodiment, packet format conforms to the OSI model,  
10 in which an application protocol (layer 5, such as FTP) uses a transport protocol (layer 4, such as  
11 TCP), which uses a network protocol (layer 3, such as IP), which uses a media access control  
12 (MAC) protocol (layer 2), which uses a physical transport technique (layer 1).

13  
14 *System Elements*

15  
16 Fig. 1 is a block diagram of a wireless communication system according to the  
17 invention in which a base station controller communicates with one or more customer premises  
18 equipment according to the invention.

19 System 10 includes wireless communication cell 11 (or a portion thereof), base  
20 station controller (BSC) 12, and one or more customer premises equipment (CPE) 13.

21  
22 Wireless communication cell 11 preferably includes a generally hexagon-shaped  
23 region of local surface area, such as might be found in a metropolitan region. Use of generally  
24 hexagon-shaped regions is known in the art of wireless communication because hexagonal  
25 regions are able to tile a local region with substantially no gaps. Although in a preferred  
26 embodiment wireless communication cell 11 includes a generally hexagon-shaped region, no

1 particular requirement exists for using that particular shape; in alternative embodiments, another  
2 shape or tiling of the local surface area may be useful.

3  
4 In Fig. 1, a portion of cell 11 includes a generally triangular-shaped region of local  
5 surface area, herein called a "sector." Sectors 14 preferably are disposed so that a set of six  
6 sectors 14 combine to form single cell 11. Thus, BSC 12 preferably is disposed at or near one  
7 corner of one of sectors 14, while CPEs 13 are disposed within the sectors.

8  
9 Although the invention is primarily described with regard to interactions that  
10 occur between BSC 12 and a single CPE 13 in a single sector 14, substantial applications of the  
11 invention exist for interactions across multiple sectors within a cell, and to interaction across  
12 sectors in multiple cells. Substantial applications of the invention with regard to multiple  
13 sectors, both within single cell and among multiple cells, would be clear to those skilled in the art  
14 of wireless communication after perusal of this application, and would not require undue  
15 experimentation or further invention.

16  
17 BSC 12 preferably includes a processor, program and data memory, mass storage,  
18 and one or more antennas for sending or receiving information using wireless communication  
19 techniques.

20  
21 Similar to BSC 12, each CPE 13 preferably includes a processor, program and  
22 data memory, mass storage, and one or more antennas for sending or receiving information using  
23 wireless communication techniques.

24  
25 In system 10, plural CPEs 13 communicate bidirectionally with BSC 12. Several  
26 CPEs 13 can share a single channel for communicating with BSC 12. BSC 12 and CPEs 13

1 preferably use time division duplexing (TDD) to facilitate the bidirectional aspect of the  
2 communication. BSC 12 and CPEs 13 preferably use time division multiple access (TDMA) to  
3 facilitate sharing of a channel among plural CPEs 13.

4  
5 In TDMA, BSC 12 grants data slots to CPEs 13. Because multiple CPEs 13 share  
6 a limited number of data slots, CPEs 13 and BSC 12 must negotiate data slot assignments through  
7 a process called contention.

8  
9 In contention, CPEs 13 that have upstream data to send to BSC 12 first send a  
10 short request (REQ) message to BSC 12. The BSC responds with a grant of a data slot for use by  
11 the CPE.

12  
13 Problems can arise in contention. Plural CPEs 13 might simultaneously try to use  
14 a single request slot to request data slots. This situation is called collision. When collisions  
15 occur, none of the CPE's request messages successfully reach BSC 12. Those CPEs 13 have to  
16 re-send their REQ messages. In order to try to allow REQ traffic to clear, CPEs 13 according to  
17 the invention can defer re-sending REQ messages for some period of time when collisions occur.

18  
19 If many request slots are defined so as to reduce a number of collisions and so as  
20 to facilitate requests by a large number of CPEs 13, or if too many REQ messages have to be re-  
21 sent, too much of available bandwidth can be used up by contention traffic. As a result, data  
22 throughput can be unacceptably decreased.

23  
24 One technique used in the prior art to reduce contention traffic is called  
25 piggybacking. In piggybacking, CPE 13 first requests a data slot. When the data slot is granted  
26 by BSC 12, CPE 13 sends data packets upstream. CPE 13 attaches a size of its current data

1 backlog to a header for one of the data packets. As a result, whenever the backlog is non-zero,  
2 BSC 12 knows to grant a data slot to CPE 13 without CPE 13 having to send a REQ message.  
3 Thus, contention traffic is reduced.  
4

5           Unfortunately, piggybacking is only effective if upstream traffic from CPE 13 is  
6 of the bursty type, so that CPE 13 needs to make only one contention request per burst.  
7 However, some important traffic sources are non-bursty. Examples of non-bursty traffic include  
8 traffic generated by online games and voice sources. Even ordinary Internet traffic running over  
9 TCP becomes non-bursty when a communication link is in heavy traffic. In the presence of  
10 non-bursty traffic, the piggyback scheme breaks down, and an excessive number of contention  
11 requests are sent upstream.

12           The invention attempts to reduce contention traffic by using a new state machine  
13 to control a contention state for a communication link between a base station controller and  
14 customer premises equipment in point-to-multipoint communication. The state can be controlled  
15 by the CPE, the BSC, or both.  
16

17           Fig. 2 is a flow chart of a state machine according to the invention.  
18

19  
20           Briefly, according to the invention, the state machine includes a grant pending  
21 absent state in which the customer premises equipment is polled with a unicast request slot.  
22 During the grant pending absent state, the customer premises equipment sends no upstream data  
23 to the base station controller but can use the unicast request slot to request a data slot for sending  
24 upstream data to the base station controller.  
25

1 By virtue of the grant pending absent state, the customer premises equipment can  
2 request a data slot without entering into contention and generating excess contention traffic.  
3 After a suitable delay without more data being received to send upstream, the state machine can  
4 exit the grant pending absent state. This delay preferably is long enough for receipt of new non-  
5 bursty data for a communication, for example 50 ms.

6  
7 In more detail, Fig. 2 shows a state machine that includes idle state 20, deferring  
8 state 21, grant pending state 22, grant pending absent state 23, unsolicited grant pending state 24,  
9 and unsolicited grant pending absent state 25. While the particular states shown in Fig. 2 are  
10 representative of a preferred embodiment of the invention, the invention also can utilize state  
11 machines that do not include all of these states and/or that include additional states.

12  
13  
14 Idle state 20 is a waiting state in which the customer premises equipment awaits  
15 arrival of data packets to send as upstream data to the base station controller.

16  
17  
18 Upon arrival of data to be sent as upstream data, the state machine transitions to  
19 deferring state 21. The state machine also can transition to unsolicited grant pending state 24  
20 upon receipt of an unsolicited grant of a data slot from BSC 24, as discussed below.

21  
22 In deferring state 21, CPE 13 sends a REQ message to BSC 12. The state  
23 machine then transitions to grant pending state 22. However, if no grant is received from BSC  
24 12 in grant pending state 22 before a timeout, the state machine returns to deferring state 21, as  
25 discussed below.

26 One possible reason for non-receipt of a grant is a collision with another CPE 13.  
Thus, deferral is needed, and CPE 13 defers sending a new REQ message for a period of time.

1 The CPE then sends the new REQ message. In a preferred embodiment, if another collision  
2 occurs, CPE 13 again defers sending another REQ message. This process preferably continues  
3 until the REQ messages gets through to BSC 12 (as evidenced by receipt of a grant) or until an  
4 error is generated (not shown).

5  
6 Preferably, each time CPE 13 defers sending a REQ message, the period of  
7 deferral roughly doubles, with a random factor included to try to avoid deferring in synch with  
8 another CPE. Thus, in deferring state 21, CPE 13 defers contending for a data slot so as to avoid  
9 collisions with other customer premises equipment.

10  
11 In grant pending state 22, CPE 13 awaits and receives grant of the data slot for  
12 sending upstream data to the base station controller and sends upstream data to the base station  
13 controller after grant of the data slot. However, if a grant is not received before a timeout, the  
14 CPE concludes that a collision or some other error has occurred, and the state machine returns to  
15 deferring state 21.

16  
17 Preferably, in grant pending state 22, CPE 13 uses piggybacking to request grant  
18 of a next data slot while sending upstream data to BSC 12. When CPE 13 sends the last data in  
19 its backlog, that data preferably is sent without piggybacking. The state machine then transitions  
20 to grant pending absent state 23 according to the invention.

21  
22 During grant pending absent state 23, CPE 13 sends no upstream data to BSC 12.  
23 No grant is pending because piggybacking was not used in the previous transmission of data to  
24 BSC 12 (hence the name of the state). Rather, CPE 13 is periodically (e.g., every 10 ms) polled  
25 by BSC 12 with a unicast request slot. CPE 13 can use this unicast request slot to request a data  
26 slot for sending upstream data to the base station controller. Thus, if more data is received by

1 CPE 13 to send upstream to BSC 12, CPE 13 can request a data slot without going through  
2 contention, thereby reducing contention traffic.

3  
4 In some circumstances, the reduction in contention traffic can be drastic, for  
5 example by an order of magnitude. Of course, the invention is not limited to such circumstances  
6 and is not limited to such drastic reductions in contention traffic.

7  
8 Upon grant of a data slot for sending new data to BSC 12, CPE 13 returns to grant  
9 pending state 22.

10  
11 If no new data is received by CPE 13 before a timeout in grant pending absent  
12 state 23, the state machine returns to idle state 20. A timeout of 50 ms has been found to work  
13 well.

14  
15 In some circumstances, BSC 12 can grant a data slot to CPE 13 without the CPE  
16 having requested the data slot. For example, if the communication between BSC 12 and CPE 13  
17 is a voice communication, BSC 12 can predict that CPE 13 will need data slots. BSC 12 can  
18 grant those data slots to CPE 13 without CPE 13 having to request them. Such a grant is an  
19 unsolicited grant.

20  
21 Accordingly, the preferred embodiment of the state machine according to the  
22 invention also includes unsolicited grant pending state 24 and unsolicited grant pending absent  
23 state 25. These states correspond to grant pending state 22 and grant pending absent state 23,  
24 respectively, with the exception that they are entered when an unsolicited grant occurs.

1           Thus, in unsolicited grant pending state 24, CPE 13 receives grant of the data slot  
2           for sending upstream data to the base station controller and sends upstream data to the base  
3           station controller after grant of the data slot, without having requested the data slot.  
4

5           In unsolicited grant pending absent state 25, CPE 13 is polled with the unicast  
6           request slot. During unsolicited grant pending absent state 25, CPE 13 sends no upstream data to  
7           BSC 12 but can use the unicast request slot to request the data slot for sending upstream data to  
8           BSC 12. The state machine enters unsolicited grant pending absent state 25 after CPE 12 has  
9           sent upstream data to BSC 12 in unsolicited grant pending state 24.

10           Pseudo-code for implementing the preferred embodiment of the invention  
11           substantially as discussed above is included in a technical appendix to this application.  
12

#### 13           *Alternative Embodiments* 14

15           The invention can be embodied in a method for controlling communication using  
16           the state machine described above, as well as in software and/or hardware such as a BSC and/or a  
17           CPE that implements the method, and in various other embodiments.  
18

19  
20           In the preceding description, a preferred embodiment of the invention is described  
21           with regard to preferred process steps and data structures. However, those skilled in the art  
22           would recognize, after perusal of this application, that embodiments of the invention may be  
23           implemented using one or more general purpose processors or special purpose processors  
24           adapted to particular process steps and data structures operating under program control, that such  
25           process steps and data structures can be embodied as information stored in or transmitted to and  
26           from memories (e.g., fixed memories such as DRAMs, SRAMs, hard disks, caches, etc., and

removable memories such as floppy disks, CD-ROMs, data tapes, etc.) including instructions executable by such processors (e.g., object code that is directly executable, source code that is executable after compilation, code that is executable through interpretation, etc.), and that implementation of the preferred process steps and data structures described herein using such equipment would not require undue experimentation or further invention.

Furthermore, although preferred embodiments of the invention are disclosed herein, many variations are possible which remain within the content, scope and spirit of the invention, and these variations would become clear to those skilled in the art after perusal of this application.

# 1 TECHNICAL APPENDIX

2 Pseudo-code copyright 2000 Aperto Networks, Inc.

## 4 4.1 State: Idle

5 ContentionWindow = 0;

6 Wait for !QueueEmpty;

7 /\* The CPE may get an unicast REQ slot in the idle state. \*/

8 /\* In this case it returns the current reqWin value \*/

9 if (unicast REQ SID == mySID) /\* Polling case \*/

10 {

11 Transmit REQ in reservation;

12 Tx\_slot = slot;

13 PrevREQ = NonContREQ;

14 }

15 if (NormalGrantId == mySID)

16 Utilize Normal Grant();

17 else if (UnsolicitedGrantId == mySID)

18 {

19 Utilize Unsolicited Grant();

20 Go to State Unsolicited Grant Pending;

21 }

22 /\* EPDU Arrives \*/

23 Enqueue();

24 CalculateDefer();

25 Go to State Deferring

## 4.2 State: Deferring

```

1  if (UnsolicitedGrantId == mySID) /* Unsolicited Grant Service */
2  {
3      Utilize Unsolicited Grant();
4      Go to State Unsolicited Grant Pending;
5  }
6  else if (NormalGrantId == mySID)
7      Utilize Normal Grant();
8  else if (unicast REQ SID == mySID) /* Polling case */
9  {
10     Transmit REQ in reservation;
11     Tx_slot = slot;
12     Go to Grant Pending;
13     PrevREQ = NonContREQ;
14 }
15 else
16 {
17     for (REQ Transmit Opportunity) /* Contention based REQ transmission */
18     {
19         if (Defer != 0)
20             Defer = Defer - 1;
21         else /* Defer = 0 */
22         {
23             if (Number of SIDs in CPE, with Defer = 0 is greater than 1)
24                 choose one SID at random;
25             if (my SID chosen)

```

```

1      {
2          Transmit REQ in contention;
3          Tx_slot = slot;
4          RTxTime = time_now;
5          PrevREQ = ContREQ;
6          Go to Grant Pending;
7      }
8  }
9  }

```

#### 4.3 State: Grant Pending

Wait for next MAP;

Move ACK pointer as per ACK field in MAP;

The next byte to transmit is set as per ACK/NACK flag and

Sequence Number in the ACK

if (Flush EPDU field set)

```

18  {
19      Flush HOL EPDU;
20      Go to Idle;
21  }
22  if (unicast REQ SID == mySID) /* Polling case */
23  {
24      Transmit REQ in reservation;
25      Tx_slot = slot;
26      PrevREQ = NonContREQ;

```

```

1      }
2      if (Normal GrantId == mySID)
3          Utilize Normal Grant();
4      else if (Unsolicited GrantId == mySID)
5      {
6          Utilize Unsolicited Grant();
7          Go to State Unsolicited Grant Pending;
8      }
9      else if (implicit collision indication received)
10         Retry();
11     else /* Error Condition: BSC did not give grant that CPE is expecting */
12         Go to Idle;

```

#### 4.4 State: Grant Pending Absent

```

13     if (First Time Entering State)
14         Count = GrantPendingWait;
15     else
16         --Count;
17     if (unicast REQ SID == mySID) /* Polling case */
18     {
19         Transmit REQ in reservation;
20         Tx_slot = slot;
21         PrevREQ = NonContREQ;
22     }
23
24

```

#### 4.5 State: Unsolicited Grant Pending

```

1  if (unicast REQ SID == mySID) /* Polling case */
2  {
3      Transmit REQ in reservation;
4      Tx_slot = slot;
5      PrevREQ = NonContREQ;
6  }
7  if (Unsolicited GrantId == mySID)
8  {
9      Utilize Unsolicited Grant();
10     Remain in State Unsolicited Grant Pending;
11 }
12 if (Last Unsolicited Grant)
13     Go to state Idle;
14
15 4.6 State: Unsolicited Grant Absent
16 if (First Time Entering State)
17     Count = UnsolicitedGrantPendingWait;
18 else
19     --Count;
20 if (unicast REQ SID == mySID) /* Polling case */
21 {
22     Transmit REQ in reservation;
23     Tx_slot = slot;
24     PrevREQ = NonContREQ;
25 }
26

```

**4.7 Function: CalculateDefer()**

```

1  if (ContentionWindow < Start)
2
3      Window = Start;
4
5  if (ContentionWindow > End)
6
7      Window = End;
8
9  Defer = Random[2^ContentionWindow];

```

**4.8 Function: Utilize Normal Grant()**

```

10  if (Grant Size == 0) /* Scheduler not able to make grant during this frame */
11
12      Go to Grant Pending;
13
14  else /* Grant Size > 0 */
15  {
16
17      while (GrantSID == mySID) /* Multiple Grants in MAP */
18      {
19
20          Extract Indicated number of bytes from SID queue;
21          Confirm that these bytes fit in the tick space allocated;
22          piggyback size = RequestWindow;
23          Transmit WPDU with Sequence Number Field set as per MAP and
24          Piggyback field set as above;
25      }
26
27      if (piggyback size > 0)
28      {
29
30          Go to Grant Pending;
31          RTxTime = time_now;
32          PrevREQ = NonContREQ;
33      }

```

1           else /\* No more bytes left in SID queue \*/

2           Go to GrantPendingWait;

3       }

4

#### 5       **4.9 Function: Utilize Unsolicited Grant()**

6       while (GrantSID == mySID) /\* Multiple Grants in MAP \*/

7       {

8           Extract Indicated number of bytes from SID queue;

9           if (#bytes == 0)

10           Tx only WPDU header;

11           else

12           {

13               Confirm that these bytes fit in the tick space allocated;

14               piggyback size = RequestWindow;

15               Transmit WPDU with Sequence Number Field set as per MAC and

16               Piggyback field set as above;

17           }

18       }

19

#### 20       **4.10 Function: Retry()**

21       Retries = Retries + 1;

22       if (Retries > 16)

23       {

24           Discard HOL EPDU;

25           Go to Idle;

26       }

1     ContentionWindow = ContentionWindow + 1;  
2     CalcDefer();  
3     Go to Deferring;  
4  
5     **4.11 Function: Enqueue()**  
6     Enqueue EPDU to tail of queue;  
7     RequestWindow = RequestWindow + Size of EPDU;